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# AFCI Gas Production Measurements: Status through 1Q FY2006


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**Joint AFCI/Gen-IV Physics Working Group Meeting**

**Salt Lake City**

**January 23-24, 2006**

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# Progress since last meeting & plans for future

- Cr – analysis completed and results sent to evaluators
- Zr – preliminary data taken; need more runs with a target set that spans a range of thicknesses
- Completed LANSCE run cycle; preparing for next with proposals for beam time due January 27, 2006
- Outside AFCI funding: Ohio University (Grimes, Massey, Hornish, Voynov) -- SSAA funded –
  - $^{13}C$, $^{14}N$ and $^{27}Al$: (n,xp) and (n,xalpha)
    - -- Nitrogen data important for nitride fuels – target characterized
    - -- Aluminum – data taken
    - -- $^{13}C$ target too thin, need to try again

## Issues for the future

- Materials – Zirconium, yes, but what else?

  Mo? Others?  - Guidance needed from program

- Improved detector – Ion chamber under development (not very expensive!)  -- will help in differentiating protons/deuterons/tritons at lower energies for improved tests of nuclear reaction models
- Larger solid angles for detectors for more efficient use of beam:  present runs are long (several weeks) and we cover only ~ 1% of 4-pi emission. (not really expensive)

# Materials of current interest span a large range in nuclear charge and mass

- Fe
- Cr
- Zr
- Ta

- Different experimental challenges
  - different lower limits to charged particle energies
  - different cross sections (high Z, lower s )
- Different emphasis on reaction mechanisms
  - Higher Z -> Pre-equilibrium more important relative to compound evaporation

# We are measuring gas production (hydrogen and helium) in neutron reactions with structural and other materials for the Advanced Fuel Cycle Initiative.

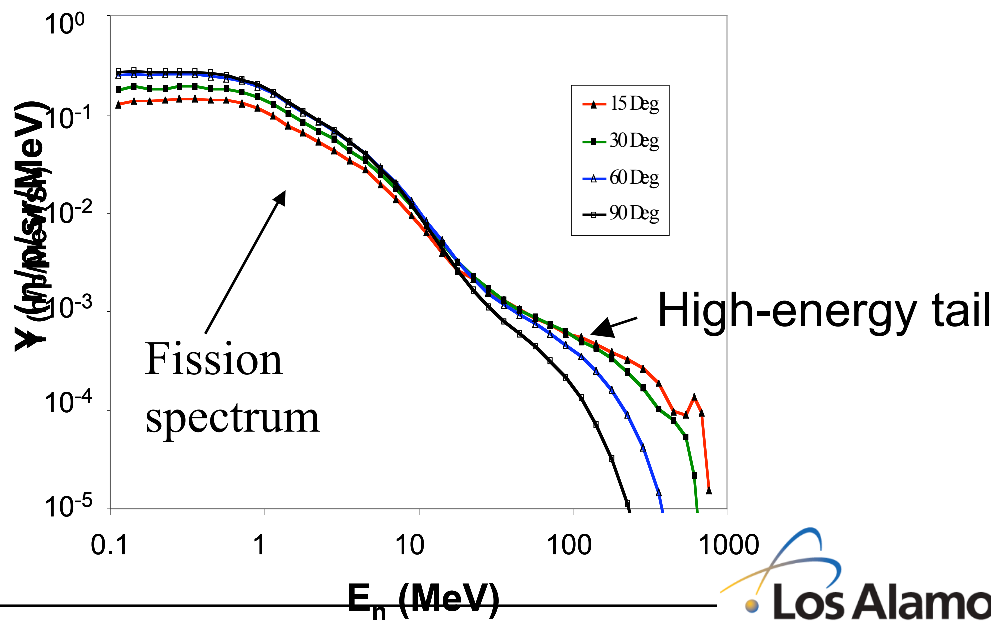
- To provide data for AFCI – "Gas Production" by neutrons on structural and other materials – e.g. Fe, Cr, Ni, Zr, Ta, W etc.
  - The cross sections are "source terms" for assessing radiation damage of materials
  - Gas production is an important component of radiation damage in materials irradiated to high fluences in advanced fuel concepts.

- To test nuclear reaction models for basic physics so that models can be used with greater confidence
  - Pre-equilibrium particle emission (e.g. C. Kalbach-Walker)
  - Nuclear level densities

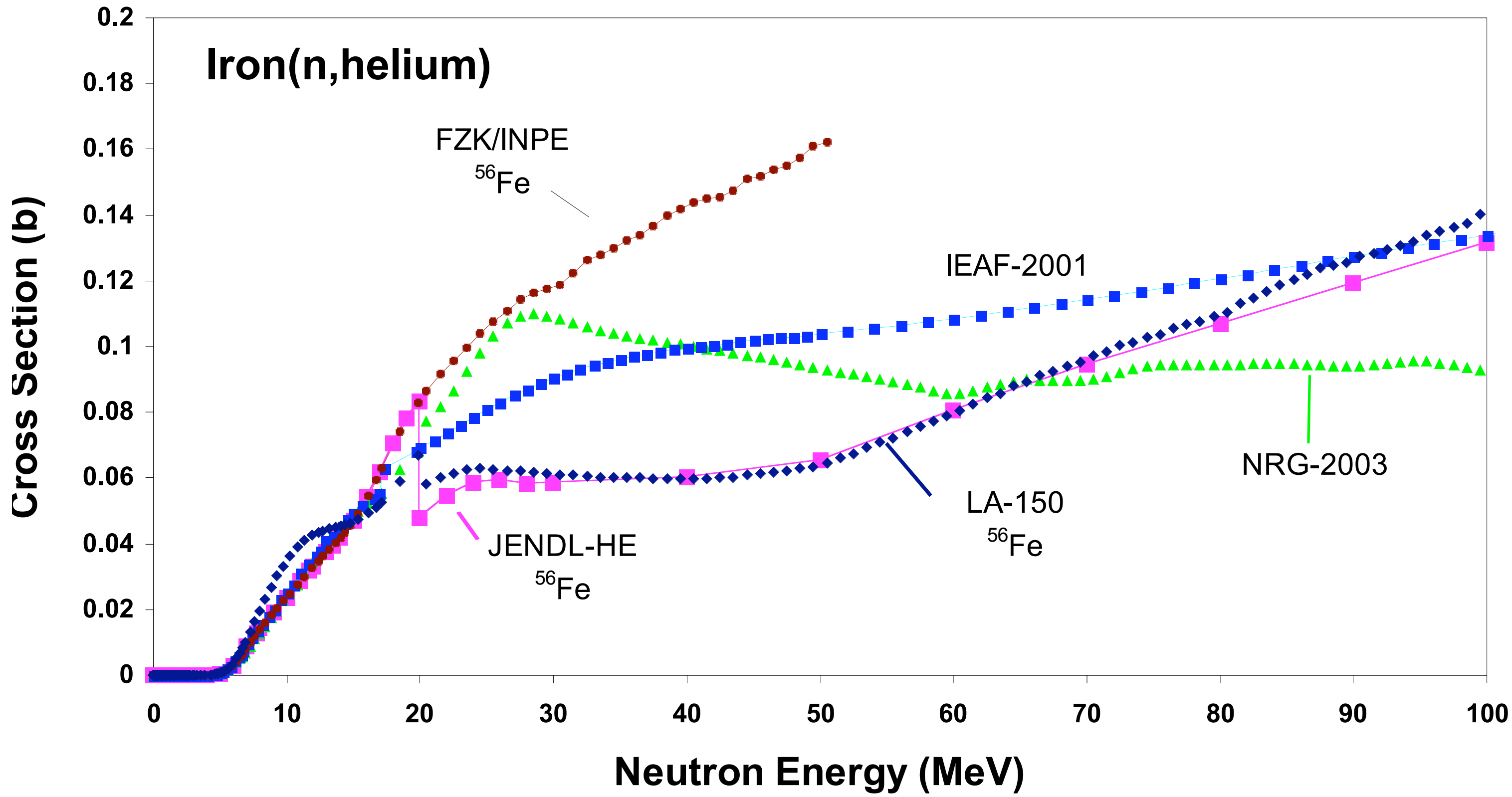
# Our energy range is from threshold (~ a few MeV) to 100 MeV

- Energy range can be studied in one experiment
- Covers reactor energies – up to ~ 10 MeV
- Covers both the lower and higher neutron energies of interest to accelerator-produced neutron sources – If they are used for radiation damage studies for fission reactors, is a correction necessary for the high energy neutrons?

For example, neutron spectrum at WNR/LANSCE



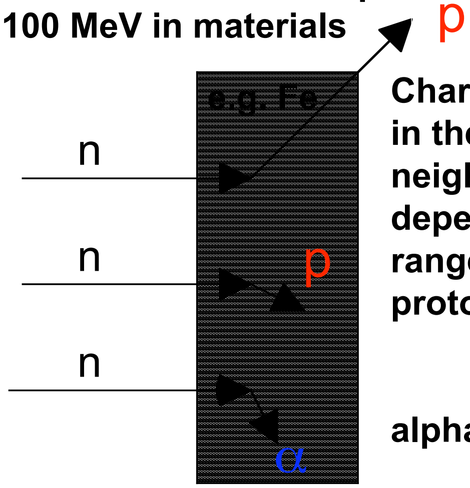
# For iron, different evaluations give very different values for helium production, especially above 20 MeV



# We measure gas production (hydrogen and helium) in thin samples

## Usual application – thick materials

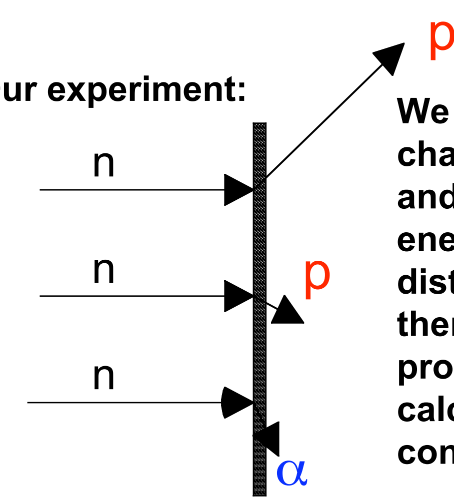
**Interactions of neutrons up to 100 MeV in materials**




**Charged particles stop in the material or neighboring materials, depending on the range:**
**protons -- mm to several cm-> hydrogen**
**alphas - mm -> helium**

## Our experiment

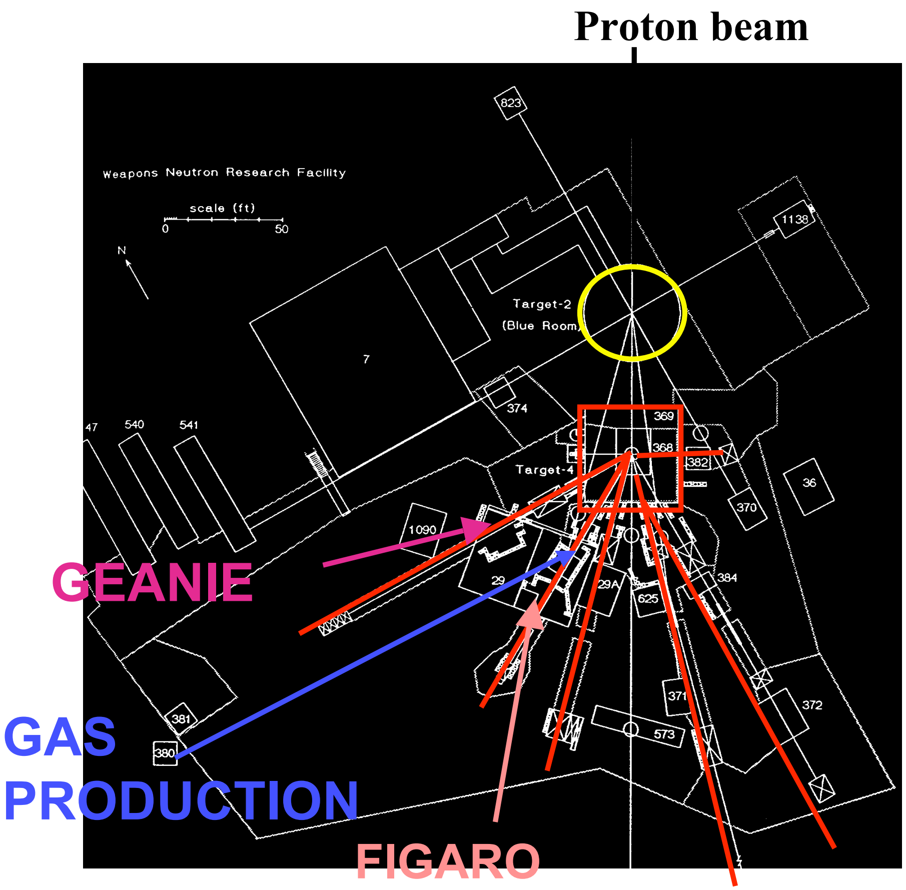
**Our experiment:**



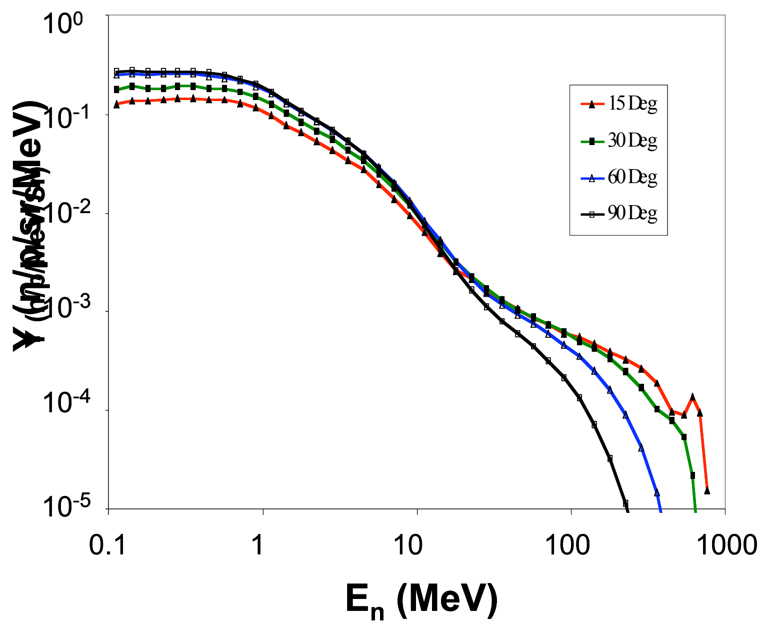

**thin foil - to let particles escape with little energy loss**

**We detect outgoing charged particles and measure their energy and angular distributions -- then H and He production can be calculated with confidence.**

# We use the 30-degree flight path at WNR to enhance the number of neutrons above 20 MeV.




Neutron spectrum extends from 1 to ~ 300 MeV; more high energy neutrons at 30-degrees.




Gas production runs concurrently with FIGARO

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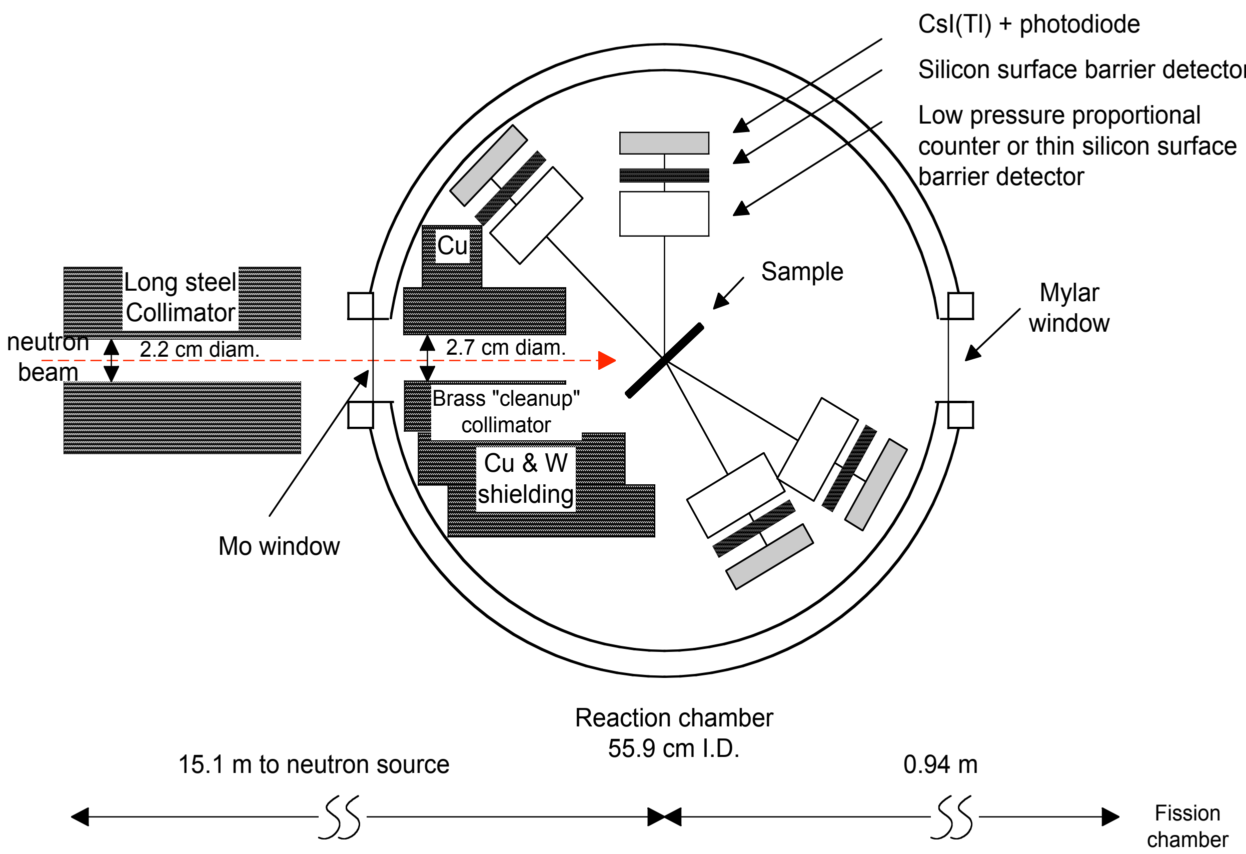
# Charged particles emitted in the reactions are identified by ΔE detectors and their energies are determined by stopping detectors of silicon or CsI(Tl)

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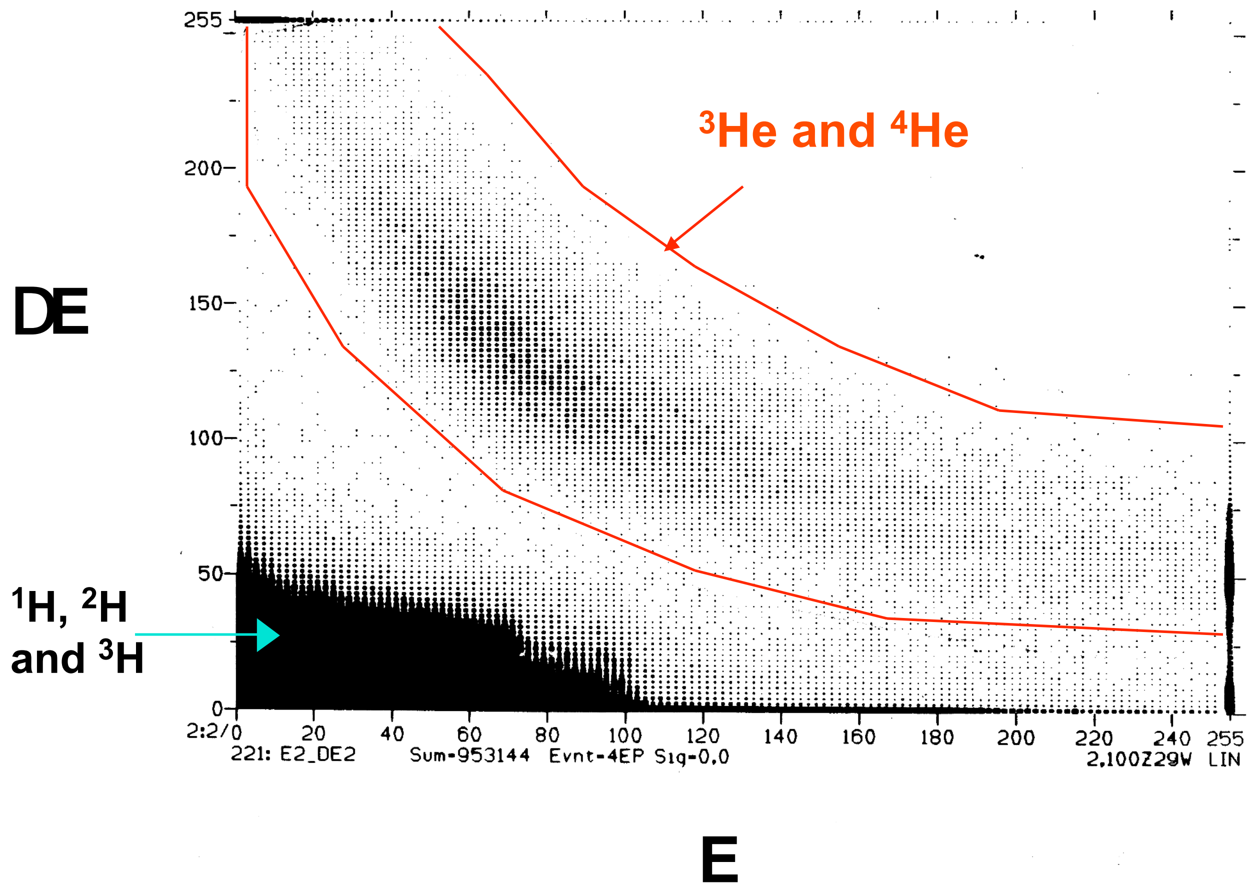
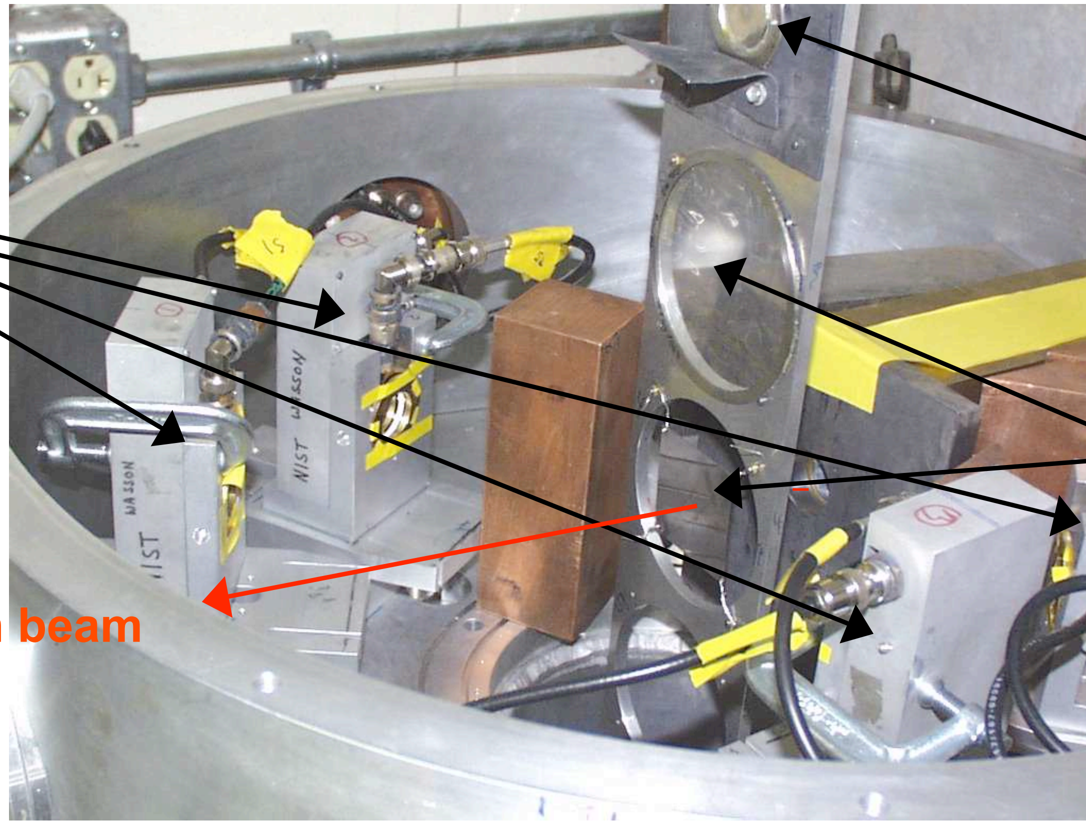
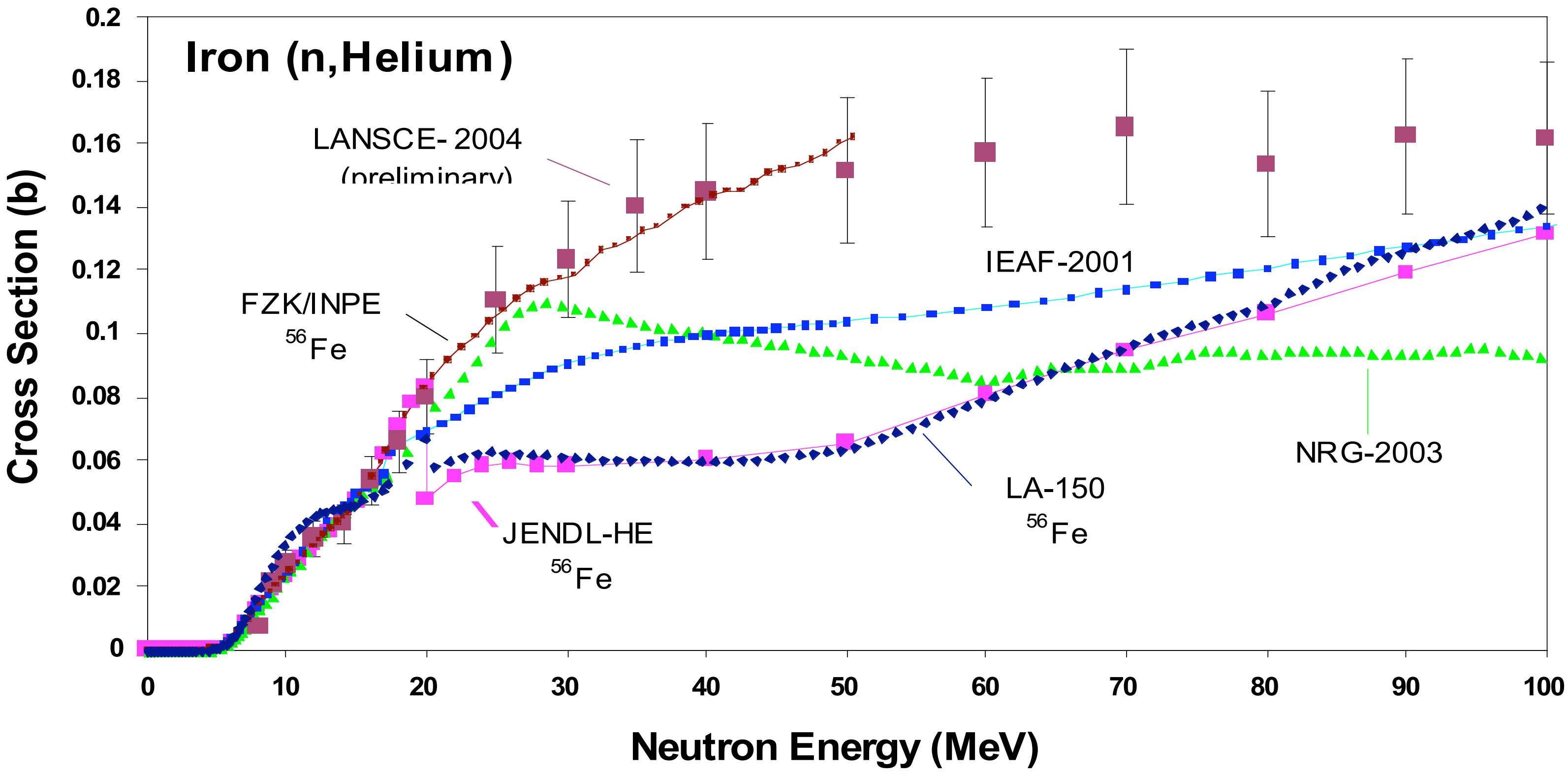
# DE-E information allows us to separate particle types



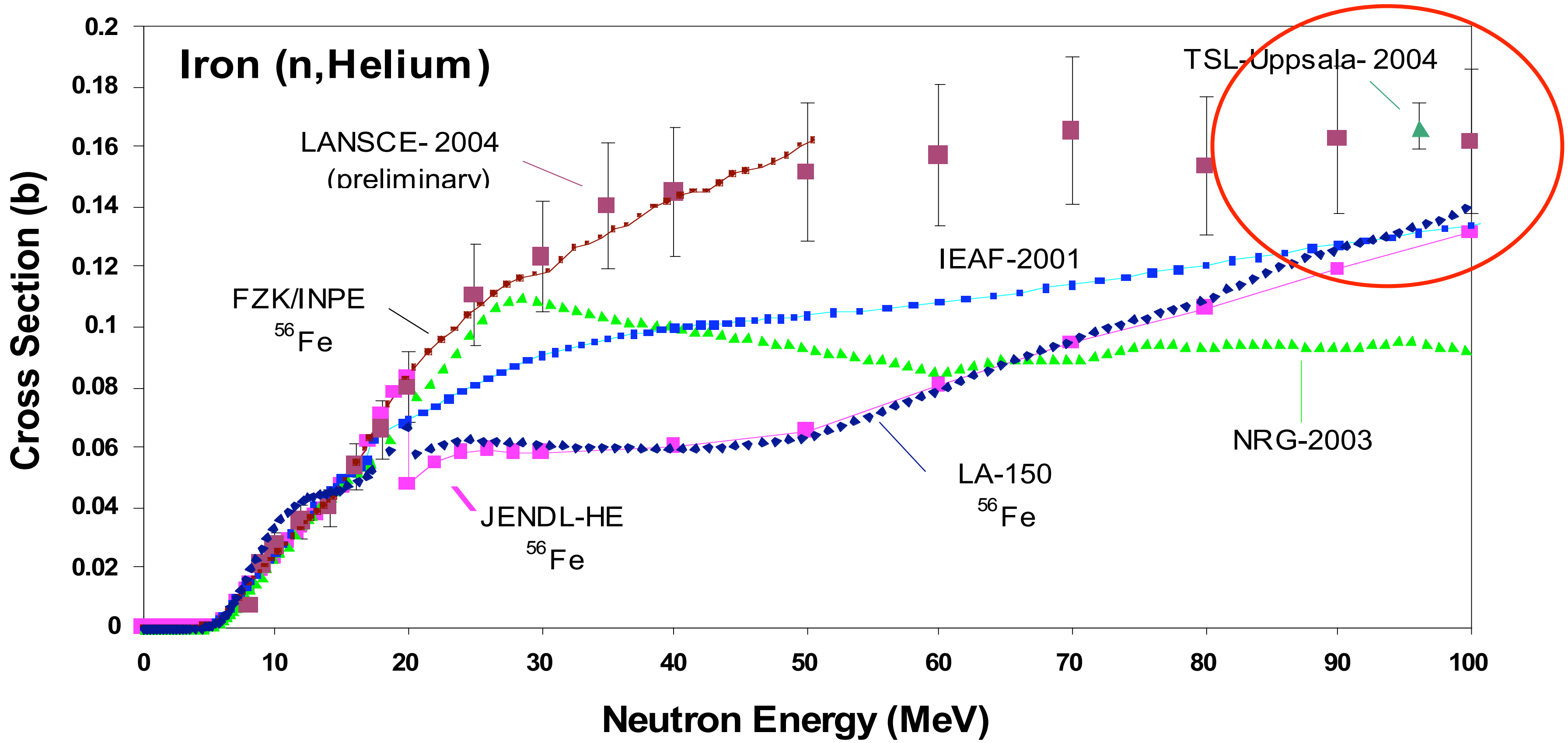
# Samples and detector telescope are positioned in a reaction chamber.



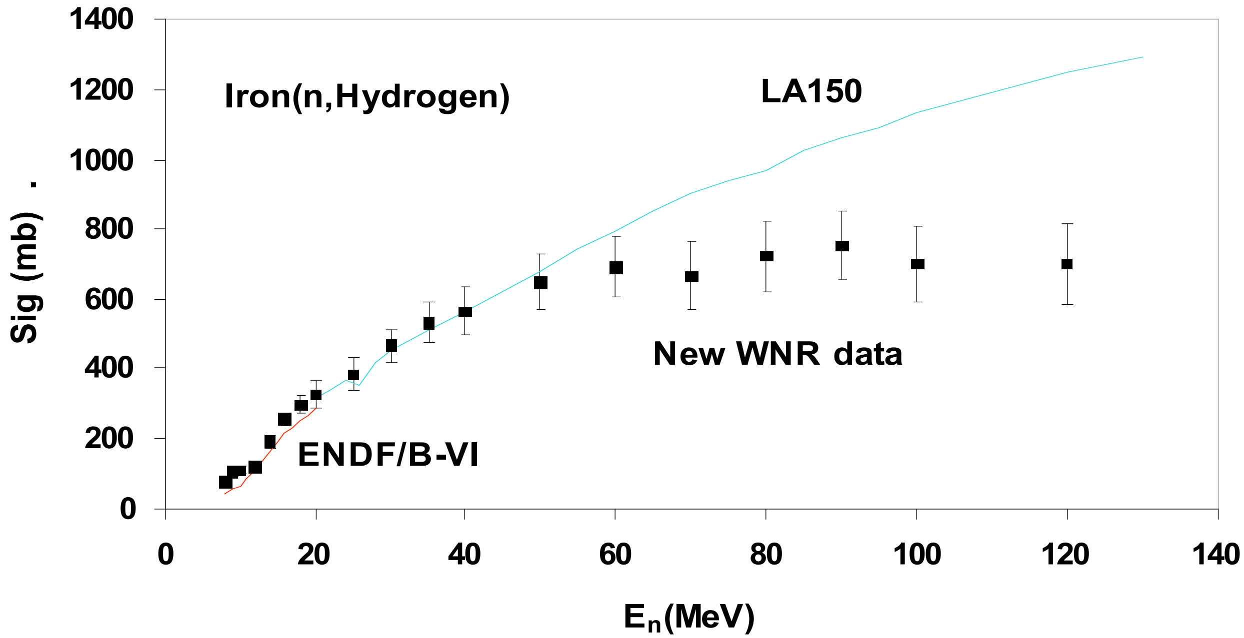
# Our data for helium production from neutrons on iron allow selection between evaluated libraries



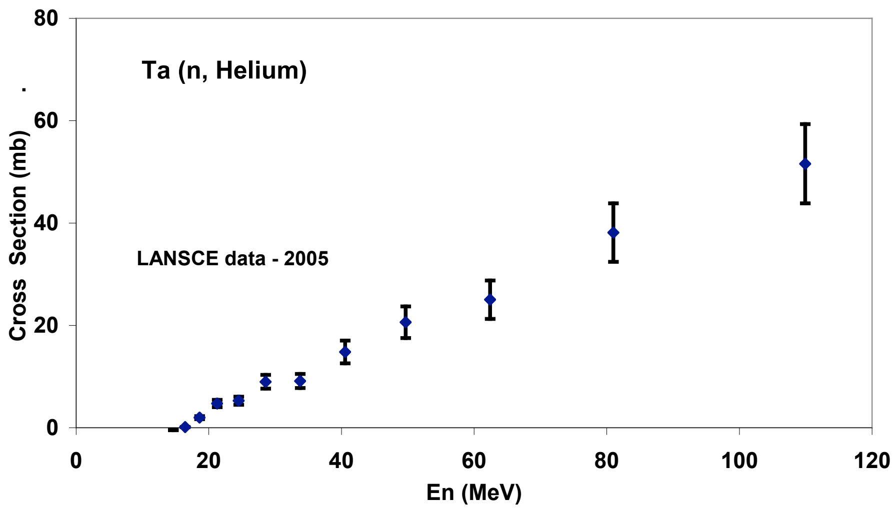
# Measurement at 96 MeV from Uppsala confirms our results

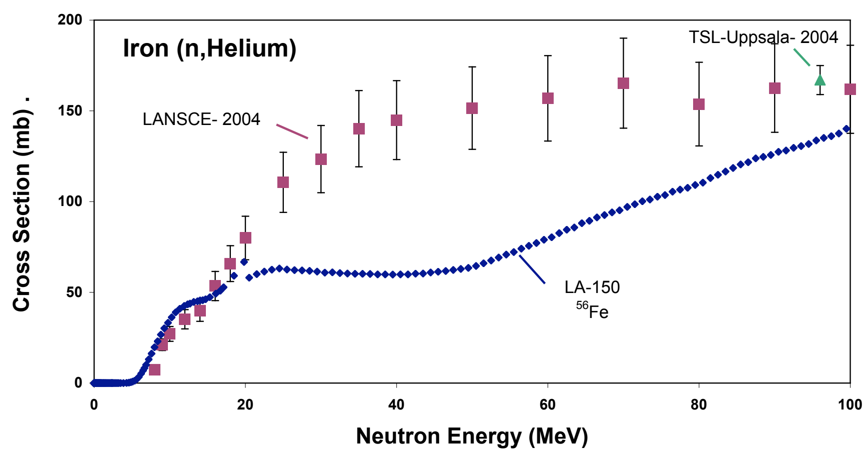


# Results for hydrogen production on iron confirmed LA150 evaluation up to 50 MeV, with disagreements at higher energies



# Results at last meeting were for hydrogen and helium production by neutrons on tantalum:  here for helium



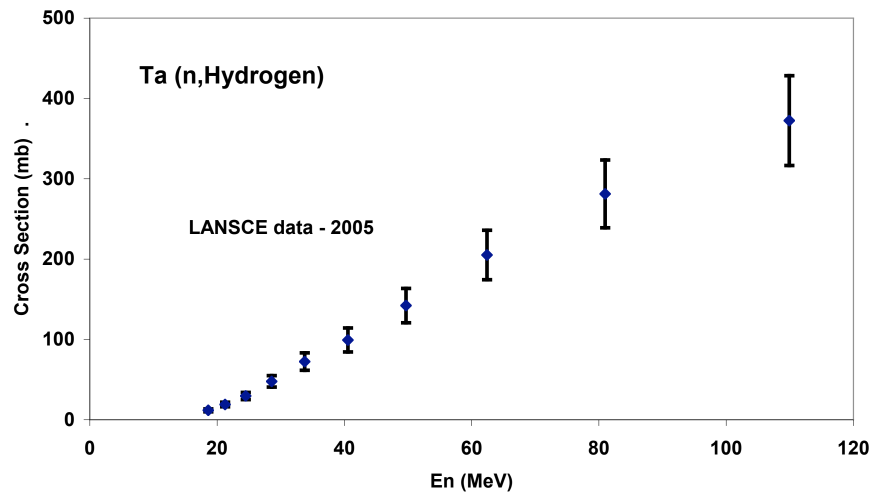



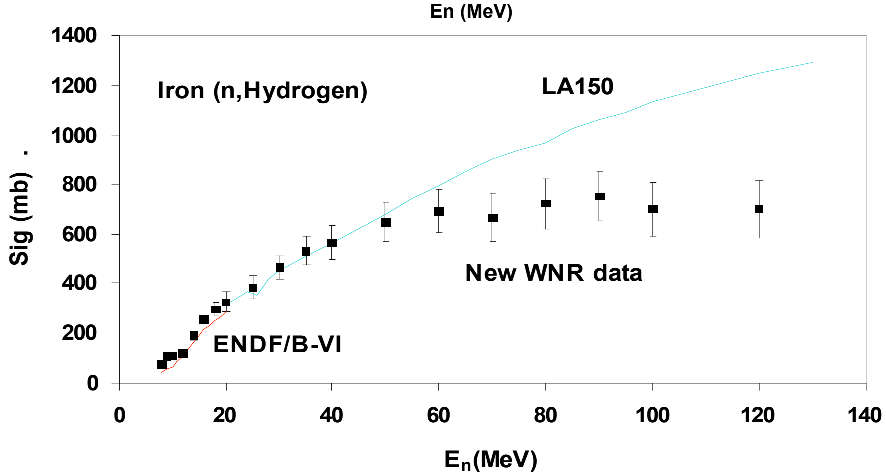

**Compare Tantalum with Iron**

- **Production in Ta less than that in Fe**
- **Different shape vs. En**

  **- iron flat above 50 MeV, tantalulm increases**
- **Ta – no LA150 evaluation yet**

# Results for hydrogen production by neutrons on tantalum led to similar conclusions




**Compare Tantalum with Iron**

- **Production in Ta less than that in Fe**
- **Different shape vs. En**
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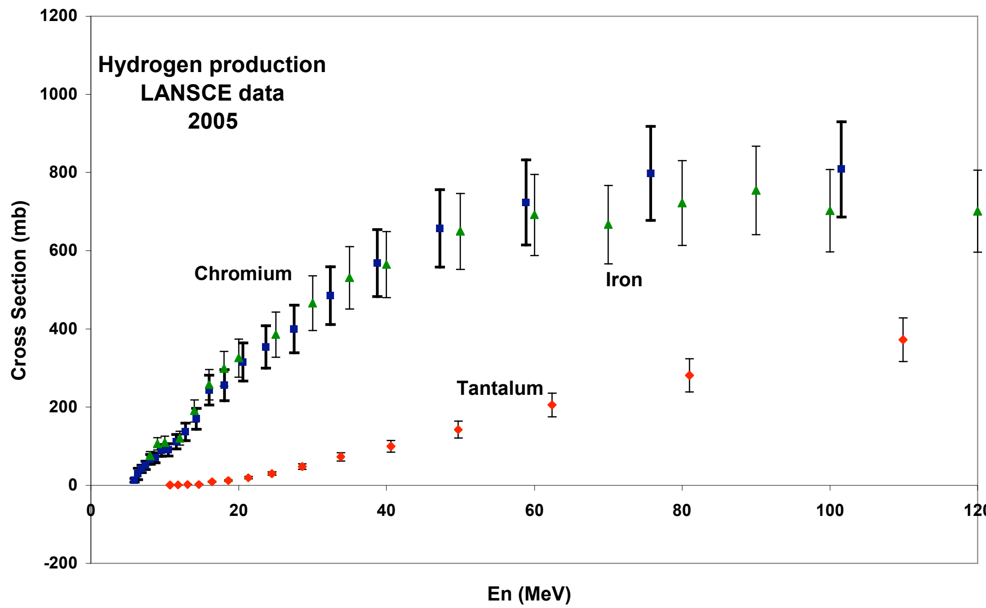
# New results are for hydrogen and helium production by neutrons on Chromium

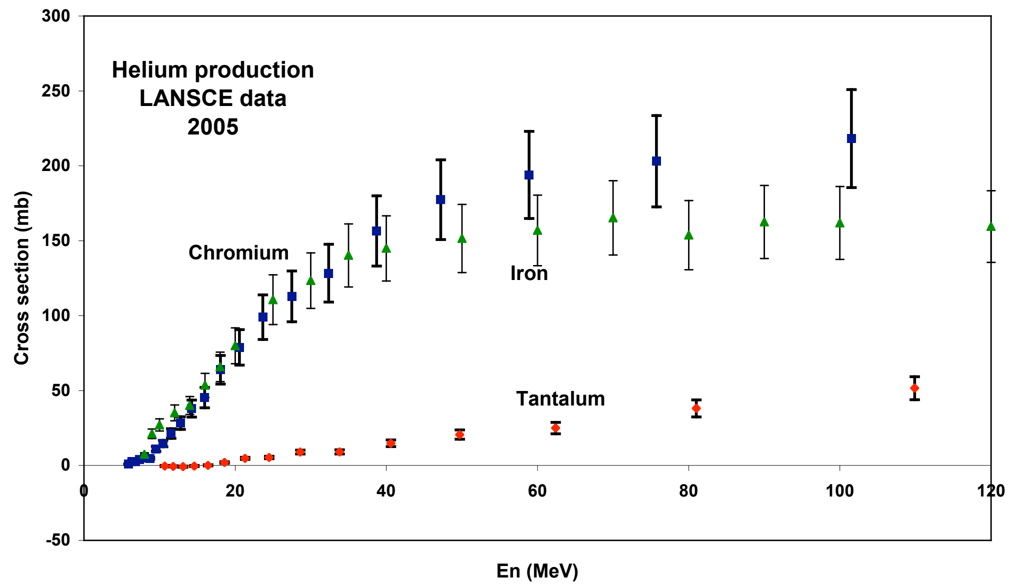
**Hydrogen production**




- Hydrogen production in chromium is very similar to that in iron
- Perhaps, no surprise: Z(Fe) = 26, Z(Cr) = 24
- Both excitation functions are flat above ~ 50 MeV
- Tantalum (Z=79) has much lower Hydrogen production cross section – but it increases with $E_n$ at least to 110 MeV

# New results for helium production by neutrons on Chromium

## Helium production




- Helium production in chromium is also very similar to that in iron (maybe a little larger)
- Perhaps, no surprise:  Z(Fe) = 26, Z(Cr) = 24
- Both excitation functions are flat above ~ 50 MeV
- Tantalum (Z=79) has much lower Helium production cross section – but it increases with $E_n$ at least to 110 MeV

## Summary

- New data for hydrogen and helium production by neutron interactions on Chromium have been determined from threshold to 100 MeV
  - Comparisons with data from Iron and Tantalum are noted and quantified.
- This technique is applicable to all materials that can be made into thin foils – therefore all structural materials and many other materials
- Some experimental improvements are underway
- Next results will be for Zirconium and other materials (Mo?) as guided by the AFCI program

One more thing:

A new capability for making fission cross section measurements on very small samples:

Lead Slowing-Down Spectrometer

# Development of a Lead Slowing-Down Spectrometer at LANSCE

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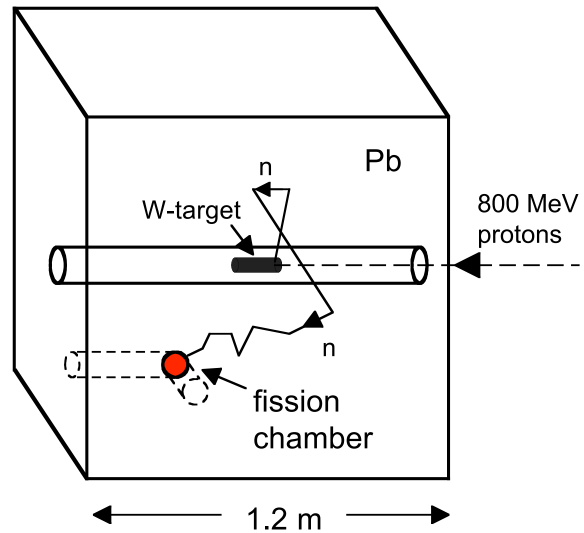
# The LSDS works by "recycling" neutrons

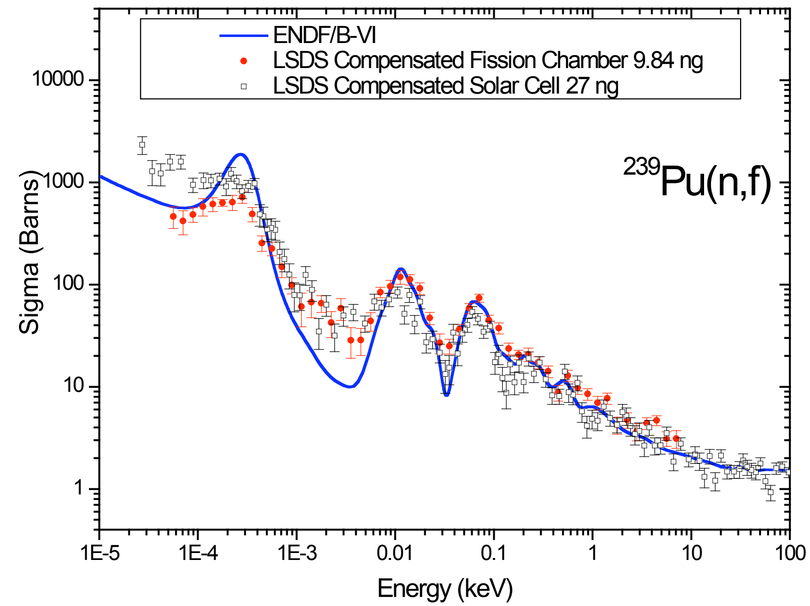
- Neutron source - pulsed
- Big lead assembly (cube)
  - Lead has small absorption cross section
  - Lead is a heavy nucleus → small energy loss for neutrons elastically scattered
  - Elastic scattering cross section approx. constant with neutron energy
- Measure reaction rate (e.g. fission) as a function of time with samples + detectors *inside* the lead
- For $E_n <$ 100 keV

$$\boxed{< E_n > = K / (t + t_0)^2}$$




# We can now measure fission cross sections with samples smaller than 10 ng

- Beam current of 1 mA of PSR beam to LSDS – radiation levels < 2 mR/hr outside of Blue Room
- Linac and PSR perform well at 40 pulses per second;  D t < 200 ns
- We have measured neutron-induced fission cross section of $^{239}$Pu with a sample of 9.87 ng. Results agree with broadened ENDF/B-VI.
- This meets our goal for measuring the fission cross section of the $^{235}$U isomer with a 10 ng sample.
- Reactions that can be studied:
  - fission
  - (n,a) and (n,p)
- Scientific areas of research
  - Fission physics
  - Astrophysical nuclear reactions (s-process)
  - Reactions on radioactive nuclides

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